LAND DEVELOPMENT AND MANAGEMENT IN TROPICAL AFRICA

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INTRODUCTION

About 300 million farmers in the tropics practice shifting cultivation and related bush fallow systems. With increasing pressure of population, the ratio of fallow to cultivation period declines rapidly and so does the fertility and productivity of the soil. It has been estimated that to meet the increasing demands for food production in the various tropical regions, the rate of land development may have to be as much as 6 to 10 million hectares per annum.

To solve this problem, an approach which is often preferred by many regional and national planners is to bring new land into large scale mechanized farming. However, the conclusions drawn recently from a critical appraisal of large-scale agricultural development schemes in savanna and forest regions of Africa and elsewhere in the tropics are not encouraging. Planning and execution of such schemes, with utter disregard of the soil conditions and other environmental and socio-economic factors, have led to widespread barren and unproductive land where lush green forest once prevailed.

Recent advances in agronomic and soil research have helped to dispel many misconceptions of the agricultural potentials of land and soil resources in different tropical regions. The completion of the Soil Map of the World by FAO/UNESCO and the subsequent development of various technical soil and land evaluation systems have provided us with more reliable information which can now be used for soil and land assessment.

Agricultural land development in developing countries, therefore, is to be based on the following prerequisites: (i) soil and land suitability, (ii) the kind of farming system to be adopted, and (iii) the socio-economic implications.

SOIL AND LAND CHARACTERISTICS

Humid Regions

In the humid and per-humid regions of the low altitude tropics (i.e. Precipitation $\geq$ Potential Evapotranspiration (P $\geq$ ET) for period between 6 to 8 months, or more than 8 months of the year, respectively), the luxurious rain-forest is often supported by the extremely infertile soils (i.e. strongly leached Ultisols and Oxisols). Land covered with such soils, are more suitable for agro-forestry or tree crop plantations, particularly in areas where population pressure is low.

The traditional bush fallow system of cultivation in such environments, though subsistence, is an effective and stable method of soil management when land availability is unlimited. More permanent food crop cultivation on such land is only possible through frequent applications of multi-element fertilizers and liming. Furthermore, periodic tree crop fallow may be required not only to recycle the plant nutrients leached beyond the surface horizon but also to improve the deteriorated subsoil structure. Large scale mechanised forest clearing of land comprising the strongly acidic and kaolinitic soils may be prohibitive. This is particularly so for land with a rolling topography and steeper slopes.

In the humid/sub-humid transition zone of West Africa (i.e. south-western Nigeria), the less leached Alfisols are the abundant soils under the predominantly secondary forest vegetation. Land-form in the region is characterized by a rolling topography with small V-shaped valleys. No-till maize farming with crop residue mulch has been shown to be a promising system of crop production on land newly cleared from forest.

Sub-humid and Semi-arid Regions

In the sub-humid and semi-arid regions of Africa (i.e. $P \geq ET$ for 4-6 and 2-4 months for the year, respectively), the upland areas are generally dominated by the "lateritic" and naturally compacted soils (i.e. kaolinitic Alfisols and Inceptisols), while the more fertile hydromorphic soils and Vertisols are found in restricted areas of inland depressions and river valleys.

The upland soils in these regions are intensively cultivated in areas where rainfall is more reliable or where supplimental irrigation is available. On the other hand, the lowland areas are generally under-utilized. In the savannah regions of West Africa, the lowland areas are mainly used for vegetable crop production such as tomato and pepper during the dry season. However, much of the land is left uncultivated throughout the rainy season because of lack of proper drainage and flood water control system. Such lowland areas could be developed for intensive rice production with better water management practices.

The Tropical Highlands

The tropical highlands of East and Central Africa comprise potentially the most productive land in tropical Africa. The fine-textured, oxidic Alfisols and Oxisols (or, Eutric Nitosols, FAO) derived from ferromagnesian rocks are widely occurring soils in the region. Such soils generally have little physical limitation and extensive food crop production systems can be developed with appropriate fertilizer use. Large scale mechanized agriculture is quite suitable for such soils, provided that supportive agro-industries are readily available.

Soil and Land Suitability

A technical soil evaluation system for highly weathered soils (or, soils with variable charge) is being developed at IITA. The principal objective of the system is to provide agricultural planners in the tropics with a set of simple guidelines for agricultural soil utilization and land development. Such soil quality and limitation guidelines are to be used in conjunction with necessary information on land-forms and agro-climatic conditions in order to assess the ultimate soils and land suitability.

The technical soil evaluation system classifies highly weathered soils in the tropics into four mineralogical groups and two chemical sub-groups which are supplimented by a set of soil physical and fertility 'condition modifiers'. The system may be briefly summarized as follows:

Table 1. A Technical soil evaluation system based on soil mineralogy (Juo, 1981).

Soil Group	Sub-group	Condition Modifiers (or Soil Fertility Limitations)	
		Physical	Chemical
Kaolinitic Soils	Eutric	w, r, c	t*, (m*)
	Dystric	w, r, c	t, k, a, (m)
Siliceous Soils	Eutric	w, c	t*, k*, (m*)
	Dystric	w, c	k, t, a, (m)

Oxidic Soils	Eutric	w	i
	Dystric	w	i, k, t, a
Allophanic Soils	Eutric	-	i
	Dystric	-	i, t, k

( ): for soils derived from parent rocks high in Mn-bearing minerals.

Brief descriptions of the 'condition modifiers' or soil fertility limitations are given below:

Physical condition modifiers:

w - Low available water reserve

r - High soil erosion hazard

c - High soil compaction hazard

Chemical condition modifiers:

k - Low potassium reserve

i - High phosphate fixation

t - Secondary and micronutrient deficiencies and imbalance

a - Al toxicity to most legume crops

m - Manganese toxicity to most legume crops

* - Potential soil toxicity and/or secondary and micro-nutrients deficiencies and imbalance due to continuous cultivation with conventional chemical fertilization.

Quantitative limits of the above 'soil condition modifiers' have been defined; but modification and refinements can be introduced as more research results are generated in the future.

Attempts are now being made to integrate the soil evaluation system with land types and agroclimatic information in order to establish a set of comprehensive guidelines for land clearing and development for the different regions in the tropics. Close collaboration with development agencies including FAO and interested national soils research institutions, will be fruitful in further developing the system.

LAND CLEARING AND DEVELOPMENT

Methods of Land Clearing:

Bringing new land under cultivation should not be done with the objective of short term gains or for doing it as cheaply as possible. Inappropriate land clearing will only lead to irreversible soil degradation which will require expensive remedial measures for soil restoration. Proper planning with due consideration to the soil and land suitability for the intended land use is, therefore, important to guarantee the successful development of land and water resources in tropical environments. The methods described below are mainly based on results obtained from land clearing studies in the forest region.

i) Manual Clearing:

In traditional systems and for small size holders clearing is usually done by hand using machete, axe, hoe and other indegenous tools. In order to ensure regrowth during the next fallowing period, stumping is generally not done. This method of clearing causes the least soil disturbance, and the problem of run-off and soil erosion is generally minimal. However, this system cannot be used for large scale mechanized farming, since, it is slow, and expensive to carry out.

Land clearing for plantation crops and pastures can also be done manually by "ring barking". This method is generally effective for eradication of trees up to certain size. Ringred trees, generally take long time to die, and the shading by standing trees can be detrimental in establishing good pastures.

ii) Chemical Poisoning:

With high risks of polluting the environment, some chemicals can be used for killing existing vegetation cover for establishment of plantation crops or pastures. The choice of the suitable chemical should take into consideration the health hazards to human and animals. The persistence of the chemicals in soils and natural waters is also an important factor to be considered.

Chemicals which are often used for tree poisoning include: 2, 4, 5-T, Naarsenite, Tordon 105 (Picloram plus 2, 4-D as trilisopropanlamine salt), 2, 4-D, Silvisor 510, sodium nitrite, and sodium chlorite which can be administered in different ways such as foliar spray, trunk injection or bark spray.

iii) Mechanized Clearing:

Development of large size farms for mechanized food production necessitate mechanized land clearing operations. Production of seasonal food crops are known to have special requirements for seedbred preparation, weed control and for complete elimination of shade. Regrowth of shrubs and other herbaceous vegetation during cropping unless controlled properly may interfere with normal farm operations and compete with crops for nutrients, water and light. Effective control of soil erosion following land clearing is another important factor to be considered. The existing plant cover should be removed in such a way that there is a minimal disturbance of the surface soil.

Suitable mechanical clearing operations may be of different types depending on the tree density, nature of the dominant species, and thickness of the underbrush growth. Some of the procedure used include knocking down the trees with (a) a heavy chain pulled between two tractors, (b) front-mounted dozer blade, (c) combination of tree pusher and root rake, (d) front-mounted heavy place as tree crusher, (e) tree extractor attachment, and (f) a flat-bottomed cutting blade that can shear the trees at ground level.

Each method has relative merits and demerits, and their use depend to a large extent on the intended land use. Any technique that causes the least soil disturbance and leaves leaf litter and other biomass on the soil surface is suited for soils susceptible to erosion (i.e. kaolinitic Alfisols and Ultisols).

Relative Efficiency of Different Land Clearing Methods

Compared with mechanized clearing, manual clearing operations are slow and inefficient. Depending on the vegetation cover and tree density, manual clearing operations may require up to 200 man-days/ha for complete clearing of a semi-deciduous rain forest (Table 2). Out of which 54 percent of the time is needed for cutting and falling, and 34 percent for stumping and burning. On the other hand, it required about 2 working hours/ha to clear with the shear blade attachment compared with 2.70 working hours/ ha required with the tree pusher/root rake combination (Table 3). Accordingly, the fuel consumption is also about 50 percent less for the shear blade than for the tree pusher attachment.

Shear blade followed by no-tillage offers good protection against soil erosion, therefore, subsequent post-clearing land development (terracing, grass waterways etc.) are not necessary. The post-clearing land development costs, depending on the method of land clearing and the soil and slope characteristics, may be as high as US $450/ha.

Effects of Land Clearing On Soil and Hydrology

Mechanical clearing and seedbed preparation by tractor-mounted equipment generally result in soil compaction and accelerate runoff and soil erosion. Data obtained from a land clearing experiment at IITA indicate that those treatments that were mechanically cleared with front-mounted shear blade attachment and those that were manually cleared suffered less soil and water loss than those cleared with tree pusher/root rake attachments and conventionally tilled (Table 4). It is interesting to point out that the soil loss/grain yield ratio ranged from 0.02 for traditional land clearing and management to 11.2 for tree pusher/root rake clearing followed by conventional tillage.

POST CLEARING MANAGEMENT AND CROPPING SYSTEMS

The post-clearing land management and cropping systems should maintain or improve the soil productivity in order to ensure a sustained and economically viable production system.

During the past decade, IITA has been conducting research as part of the effort to replace or improve traditional bush fallow methods with more productive systems. Our scientists have identified several promising technologies for soil and crop management. Among them are: (i) No-till maize farming, (ii) Alley cropping, and (iii) Live mulch cropping systems.

Each of these technologies are being evaluated from agronomic and economic points of view and further research is, required before they are ready for adoptation under different soil and agroclimatic conditions.

No-till Farming

No-tillage is essentially farming without plowing, where seeds are planted in a narrow slit or trench opened mechanically in the killed sod or previous crop residue. Weed and other competing vegetation are controlled by chemical herbicides, and plant roots are left in the soil to decompose.

In the forest zone of West Africa, where the highly erosive Alfisols with low nutrient and water holding capacities are dominant, the no-till maize production with crop residue mulching on newly cleared forest land has shown distinct advantages over conventional tillage. In comparison with conventional tillage, the no-till system has the following advantages:

(i) Soil erosion caused by water or wind is drastically reduced.

(ii) Sloping lands that cannot otherwise be used for row crops can be used with a minimum risk of soil erosion and degradation. The cost of installation and of maintenance of traditional soil erosion control measures (terraces) is reduced.

(iii) Energy requirements are reduced.

(iv) The time required for land preparation is reduced, that provides more flexibility in planning farm operations.

(v) The investment in machinary is reduced.

(vi) Soil-water and nutrient reserves are used more efficiently.

Research conducted at IITA and elsewhere have shown that if the vegetation cover is removed for arable landuse, a crop residue mulch of 4 to 6 t/ha provides adequate protection to the soil against the impacting raindrops and prevent soil erosion. The effectiveness of residue mulch is considerably enhanced if the soil surface has not been disturbed by mechanical manipulations such as caused by plowing and inter-cultivation. These requirements for soil and water conservation can be met through the use of the "notill" system.

Experiments conducted at IITA for the last ten or more years have indicated that, at least on slopes upto 15 percent, continuous maize production can be practiced without serious erosion risks (Table 5), provided that zero tillage is used together with crop and weed residues maintained as a mulch. Maize yield (total of 2 crops per year) with zero tillage have proven to be superior than the conventional tillage (Fig. 1). But the significant yield decline after the fourth year under both tillage systems are due to a variety of factors. Soil compaction and soil acidification are among the important ones. These data point out the limitations for the utilization of the so-called "kaolinitic" or "low activity clay" soils for continuous food crop cultivation. To overcome such soil limitations, periodic chiselling, returning land to planted fallow with deep rooted perennials, or ploughing at the end of the rainy season are currently being studied.

Moreover, for the no-tillage system to be successfully adopted, a package of agronomic practices must be developed for different soils, crops and agroecological environments. The cultural practices recommended for the conventional plowing system are not always suitable for the no-tillage system. Agronomic and economic studies on the following spects are being developed and strengthened at IITA

(i) effective control of insects and disease-producing organisms, and the rodents that are likely to be more in notillage than in conventional tillage system.

(ii) alternative methods of adequate weed control if appropriate herbicides are not available, and

(iii) suitable cropping systems to meet the residue requirements for soil and water conservation and for alternate uses (fuel, fodder, fences etc).

Alley Cropping

Alley cropping is a system, in which arable crops are grown in the spaces between rows of planted woody shrubs or tree fallows in which the fallow species is periodically pruned during the cropping season to prevent shading and provide green manure for the companion crop.

The alley cropping system retains the basic features of bush fallow. It offers an attractive alternative and may be easily adopted by the small farmers in tropical Africa. Major modifications are as follow:

(i) Selected species of fast-growing small trees and shrubs (usually legumes with nitrogen-fixing ability) are used to replace the variable species of the naturally-regenerated bush fallow.

(ii) The small trees or shrubs are planted in rows with interrow spacing wide enough to allow the use of mechanized equipment. (Different spacings were tried - 2, 4, 6 and 8 m. There are drawbacks to both the too narrow and the too wide spacings).

(iii) Trees are cut back and kept pruned during the cropping period and leaves and twigs applied to the soil as mulch and nutrient source. Bigger branches are used as stakes or firewood. Fire is never used for land clearing or tree suppression.

(iv) The trees which are allowed to recover during the dry (off) season develop new growth which is used on the succeeding crop.

Promising results were obtained from "alley cropping" trials with maize and Leucaena leucocephala conducted at the IITA site in Ibadan. Leucaena planted in rows 4 m apart and intercropped with maize produced substantial amounts of pruned top dry matter and N yield which benefitted the associated maize crop. The use of Leucaena tops maintained maize grain yield at a reasonable level even with no nitrogen input on a low-fertility, sandy Inceptisol. The nitrogen contribution by Leucaena mulch on maize grain yield was equivalent to about 100 kg/ha for every 10 t/ha of fresh prunnings (Table 6). The continuous addition of pruned material to the soil along with the barrier formed by the Leucaena rows also reduces run-off and soil erosion. The system of continuous bush fallow as observed in "alley cropping" is expected to retain soil productivity for a long period and permit more effective use of the land.

Further studies are being conducted to evaluate the applicability of the system to the sub-humid and per-humid regions. Other tree and shrub species that are known to be effective in restoring soil fertility under adverse soil conditions are currently being tested.

Live Mulch Cropping Systems

The system involves that food crop such as maize is planted directly in a living cover of a low-growing plant (legumes or grasses) with minimum soil disturbance.

The live mulch crop production system incorporates the soil conservation features of organic mulch and no-tillage but has the advantage of smothering weeds. It also has a potential to become an effective alternative to manual, mechanical, and chemical methods of weed control.

The system also has the advantage that the legume live mulch contribute nitrogen to the system. Encouraging experimental results of the effect of live mulch on crop yields have been obtained (Table 7). Maize response to fertilizer also differed with the type of ground cover. Yield was significantly higher in live mulch plots that did not receive any fertilizer than in similarly treated bare (no tillage) and conventional tillage plots. When fertilizer was applied to both live mulch and bare plots, maize yield in live mulch plots was either better or as good as that from bare and conventional tillage plots.

Results obtained so far show that the need for weed control as a crop production input can be eliminated in established live mulch covers and that the requirement for fertilizer can be minimized. Further studies will be directed at identifying the range of crops and agro-ecologies in which the live mulch crop production can be practiced. These studies will also investigate pest dynamics and long-term effects of live mulch covers on soil physical and chemical properties.

Table 2. Time (man-days/ha) required for traditional and manual clearing operations (Couper, Lal and Classen, 1981).

Operation	Complete clearing	Traditional clearing
Underbrush	21 ± 5	21 ± 5
Cutting and felling	96 ± 32	5 ± 1
Stumping and burning	60 ± 26	27 ± 6
Total	177 ± 9	57 ± 21

Table 3. Operating time required for mechanized clearing (Couper, Lal and Classen, 1981).

Clearing attachment	Machine time (hrs/ha)	Man-days/ha	Fuel consumption (l/ha)
Root Rake/Tree Pusher	2.7	25	123.8
Shear Blade	1.9	29	78.5

Table 4. Effects of methods deforestation on runoff and erosion (Lal, 1981).

Clearing treatment	Runoff (mm)	Soil Loss (t/ha)
Traditional	2.6	0.01
Manual clearing - notillage	15.5	0.4
Manual clearing - conventional tillage	54.3	4.6
Shear blade - no tillage	85.7	3.8
Tree pusher - no tillage	153.1	15.4
Tree pusher - conventional tillage	250.3	19.6

Table 5. No tillage effects on soil and water loss under maize (Lal, 1976).

Slope	Soil Loss (tons/ha)		Runoff (mm)	
	No tillage	Plowed	No tillage	Plowed
1	0.03	1.2	11.4	55.0
10	0.08	4.4	20.3	52.4
15	0.14	23.6	21.0	89.9

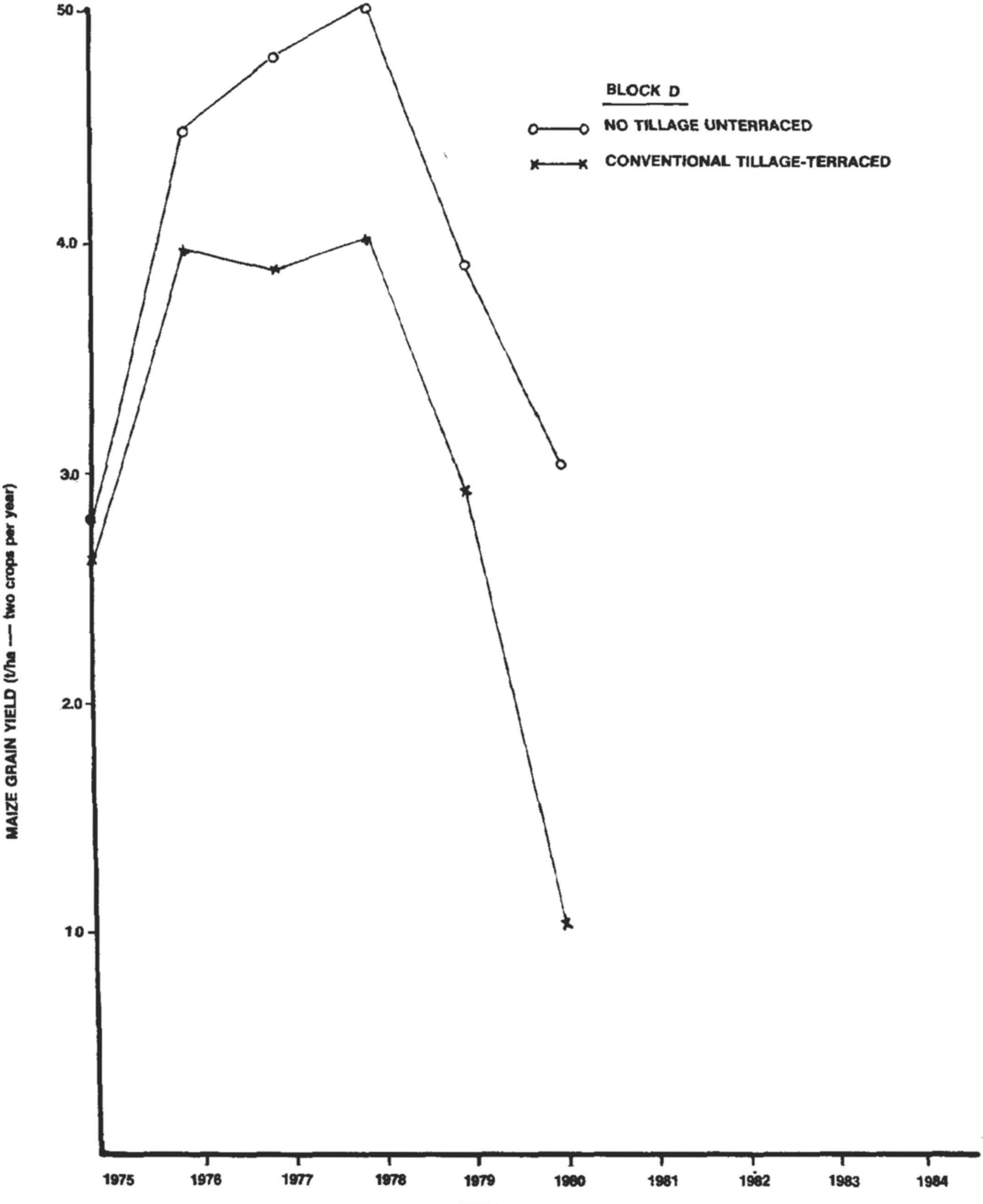

Fig. 1. Grain yield of maize (Cv. TZPB) under no-till and conventional tillage on a kaolinitic Alfisol cleared from secondary forest, IITA, Ibadan.

Table 6. Effect of application of nitrogen and Leucaena prunings on grain yield of maize grown in alleys between leucaena hedge rows in 1980 (Kang et al.).

Nitrogen rates (kg N/ha)	Leucaena Prunings	Main Season	Minor Season	Total
		kg/ha		
0 - N	Removed	1036	754	1780
0 - N	Retained	1918	1573	3491
40 + 30 N*	Retained	2648	2310	4958
80 + 60 N*	Retained	3258	2703	5961
LSD 05	-	312	278	

*Main season maize received 40 and 80 kg N/ha. Minor season maize received 30 and 60 kg N/ha.

Table 7. Effect of ground cover and fertilizer level on maize yield (t/ha). Early maturing maize (cv. TZE 4). (I.O. Akobundu, unpublished data).

Ground cover		N-fertilizer level (kg/ha)			
		0	60	120	Mean
CONVENTIONAL TILLAGE	Early season 1979*		4.37	-	
	Late " 1979	1.48	3.40	3.11	2.54
	Early " 1980	1.24	1.49	1.51	1.41
	Late " 1980	0.67	1.69	1.31	1.22
NO TILLAGE	Early season 1979*	-	3.88	-	
	Late " 1979	0.68	2.78	3.47	2.31
	Early season 1980	1.63	2.70	2.51	2.28
	Late " 1980	1.30	2.98	2.67	2.32
PSOPHOCARPUS	Early season 1979*	-	3.27	-	
	Late " 1979	2.15	3.00	2.62	2.59
	Early " 1980	2.47	2.39	2.41	2.42
	Late " 1980	2.04	2.43	2.73	2.40

* Late maturing maize (cv. TZPB) was used for uniform first cropping of the field following legume cover establishment in the previous year (1978).

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